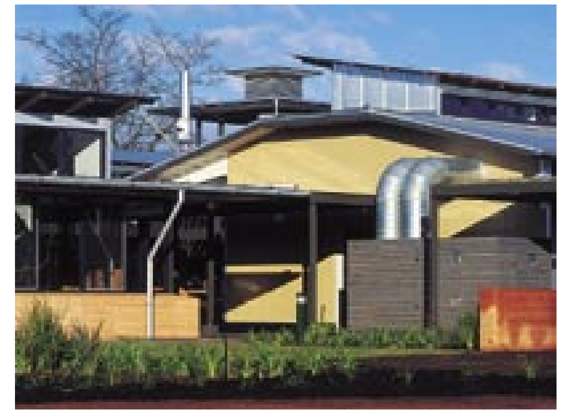
Environmentally Sustainable Design

01



02

03

04

05

Border Control.

Continuing our series of case studies on environmentally sustainable architecture, Lindsay Johnston assesses the new buildings at the Thurgoona campus of Charles Sturt University.

Architectural Review Australia **(73 Spring 2000)** reviewed buildings at the Albury Thurgoona campus of Charles Sturt University by Marci Webster-Mannison. Here we review the TAFE National Environment Centre buildings on an adjoining campus by Lindsay and Kerry Clare and the NSW Government Architect's Department under Chris Johnson. In *ar* 73 we reflected on the fact that a major RAIA Environment Award had eluded the Charles Sturt buildings. In 2001, Marci Webster-Mannison did receive a special jury award in the RAIA NSW awards (possibly spurned by *ar* comment), but the Albury Thurgoona TAFE buildings similarly missed out on the State ESD/Energy Efficiency Award. Both projects are, however, quite exemplary in the ways that they have approached issues of environmental sustainability and energy reduction, although they have approached these issues from quite different architectural directions.

With the Charles Sturt buildings, it was hard to fault the thoroughness of the thinking that underpinned the approach to sustainability in the widest possible context – it was the architectural language that raised the question – "is a building that sits outside the continuum of current norms of 'good architecture' as determined by criteria of style, but which performs exquisitely, any less good architecture than an exquisite stylistic 'piece' that performs poorly?"

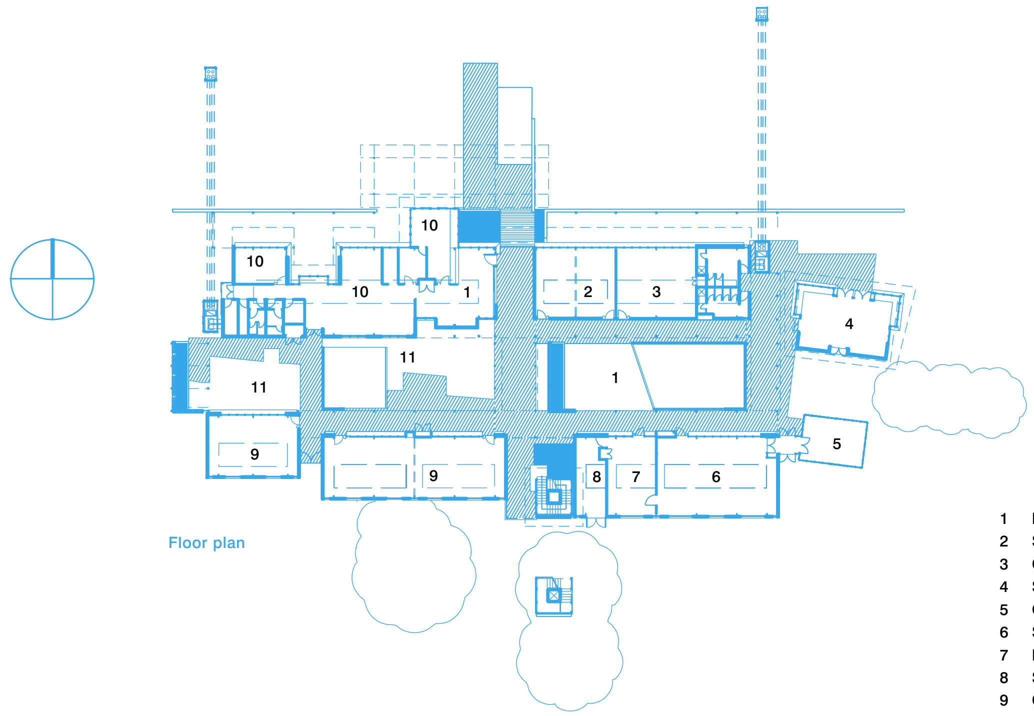
The TAFE National Environment Centre, with the participation of the Clares, comes from excellent bloodlines in the, now, mainstream of Australian award-winning and widely published architecture. In addition, with the participation of the NSW DPWS EES (Environmental and Energy Services) team, including Zig Peshos and Eric Yeo, the buildings have been designed with thorough and well-informed attention to, what I call, the 'holy trinity' of life cycle assessment – utilisation energy, embodied energy and environmental performance. It is fascinating, therefore, for readers to examine these case studies of two educational projects located on adjacent sites that confront identical climatic conditions and similar user needs.

Architectural language. The design solution has been strongly driven by the environmental agenda and responses to the demands of the climate and place. Overlaid on this is a refined and controlled language of materials and detailing that reflects precedents in the work of Lindsay and Kerry Clare. They have always instinctively responded to climate and place and this project extends the continuum of their work into a more qualitative and scientific approach. Functional honesty is, in their case, not just a modernist symbolic functionalism – 'you can see what happens inside'. Their bits always fit together beautifully and in this case what really 'happens inside', in terms of energy performance and environmental comfort, has possibly become the predominant 'bit'.

Location and climate. Albury is located 570 kilometres south west of Sydney and is 300 kilometres from the east and south coasts. The summers are hot and dry with maximum daytime temperatures reaching a severe 44˚C and mean daytime temperatures around 30˚C, but with the advantage of high diurnal (daily – day/night) swing to mean night lows of around 14˚C. There are strong dusty summer winds and afternoon humidity is low at around 33 percent. Winters are cold with temperatures frequently falling to below 0˚C, nights down to as low as -7˚C and mean daytime temperatures around 13˚C. Annual rainfall averages 760mm. The design team accessed a detailed weather analysis from Albury airport.

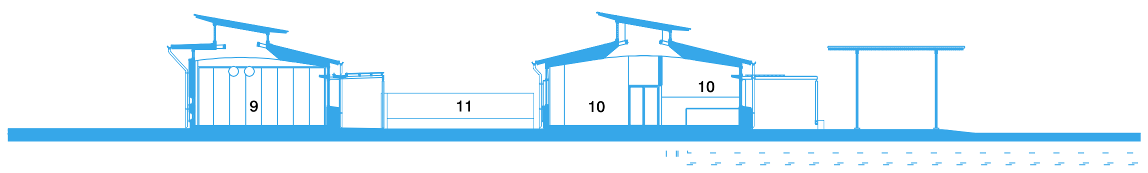
01 The building elements are grouped to enclose a sequence of central courtyards, reminiscent of those in Middle Eastern houses.
02 & 03 The external language of the facility exposes its basic functions.
04 Vegetation and water features punctuate the courtyards.
05 View into the central courtyard, which has become a protected environment that acts to regulate temperature variations.

TAFE National Environment Centre. Albury, NSW
Lindsay & Kerry Clare. Architects
Lindsay Johnston. Review
Anthony Browell. Photography

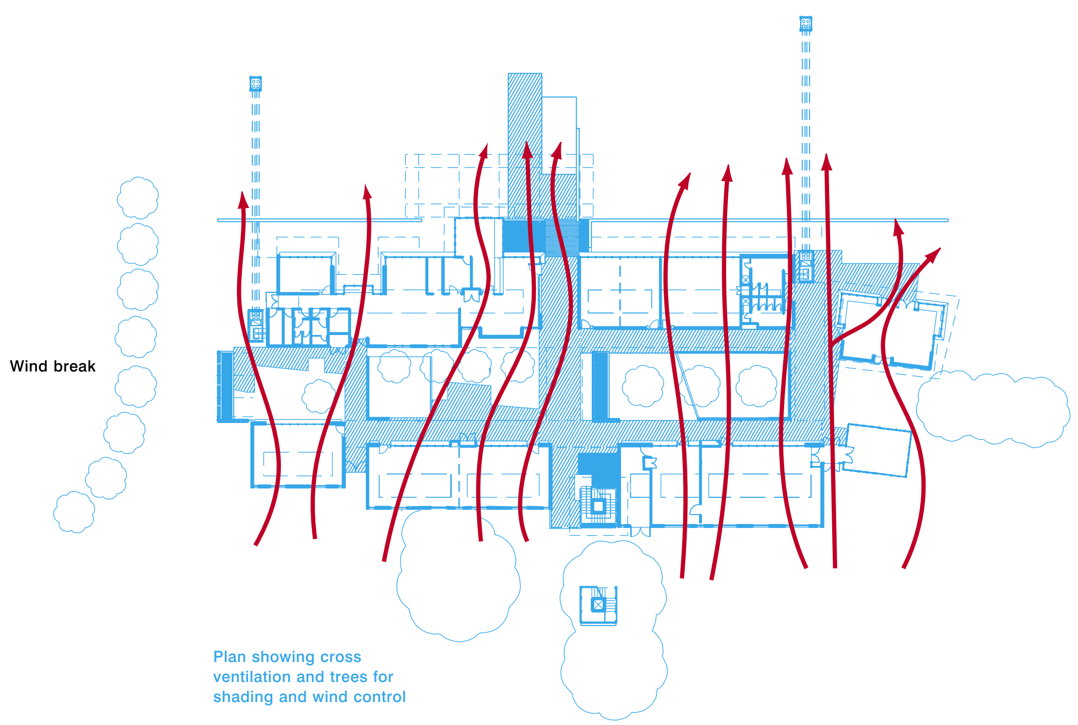


Floor plan

1 Foyer
2 Seminar
3 Computer room
4 Staff/students amenities
5 Greenhouse
6 Science workroom
7 Prep room
8 Student project store
9 Classroom
10 Office
11 Courtyard



Typical cross section



Plan showing cross ventilation and trees for shading and wind control

Project description. The TAFE National Environment Centre is nine kilometres out of Albury on a site of 125 hectares of undulating grassland. The accommodation includes three classrooms, a rural science laboratory, a computer room, administrative offices, public exhibition space, seminar rooms, staff and student recreation areas and a glasshouse. TAFE required that the buildings would demonstrate good environmental design practice to complement the environmental curriculum.

Design team modus operandi and modelling. Emphasising the importance of collaborative design, the whole team, including environmental consultants, conducted a brainstorming charet at the first conceptual stages, followed by subsequent charets as the design evolved. Initial intuitive design processes were tested and validated by computer modelling of typical building elements using 'Ecotect', a software suite developed by Dr Andrew Marsh of University of Western Australia, and 'Radiance', to assess thermal performance, energy demands and daylight. The Clares regret that the procurement arrangements for the project distanced them from site supervision.

Key design features. A central courtyard that is isolated from the external landscape creates a protected microclimate that mediates temperature variations. Planning, section design and construction methods contribute to passive environmental control. An innovative system of ground source cooling and heating utilises stable below ground temperatures to modify supply air temperatures. A minimal technical system of gas heating and evaporative cooling supplements the passive systems. Longevity, adaptability and eventual disassembly are promoted through the use of structural portal frames and non-loadbearing internal walls.

Planning. The buildings are correctly set out on an east to west axis thus maximising northern solar access and minimising east and west exposure. Large windows face to the north, small windows to the south and east and west windows are avoided. The buildings are single loaded allowing cross ventilation from south to north. The building elements are grouped to enclose a main sequence of central courtyards.

Courtyards. The courtyards are screened from the outside environment, and filled with vegetation and water features. Roof overhangs and deciduous vegetation provide shade in summer. Gates around the courtyards can be opened and closed to regulate airflow – admitting cool summer breezes and giving protection from hot summer and cold winter winds. The designers cite the courtyards of Middle Eastern houses which provide shade and hold cool night air into the heat of the day (Gideon, 1980 *Housing in Arid Lands: Design and Planning*, The Architectural Press). A similar principle has been attempted at Thurgoona TAFE, but the courtyard appears to be insufficiently enclosed to perform as a significant reservoir of night-time 'coolth' into hot summer days. Conversely, the width to height proportion of the courtyards has been established at 2.5-3.5:1 to encourage air movement.

Loggias. The designers also cite the Middle Eastern loggia concept where small apertures on the windward side of an enclosure, opposite a wide opening on the leeward side, create a 'claustra', or narrowing, which induces accelerated air movement thus creating physiological cooling (Fathy, 1986 *Vernacular Architecture – Principles and Examples with Reference to Hot Arid Climates*, University of Chicago Press). Physiological cooling is achieved by induced air movement over the human body and can be applied both outside and inside buildings using basic aerodynamics or by mechanical means, such as fans. The western screen wall to the central courtyard area, which cuts out the hot low western sun, is punctuated by small apertures to accelerate wind speed in summer that passes over a water trough. It is hard to assess the beneficial impact of this arrangement.

Outdoor cooling. Low summer humidity and associated low wet bulb temperatures (measured with the bulb in a wet 'sock') in Albury offer the potential to use evaporative cooling – the humidification of the air – to lower dry bulb temperatures. Mist sprays have been provided in the outside courtyard areas to lower hot summer temperatures (Konya, 1984 *Design Primer for Hot Climates*, The Architectural Press). A dam is located to the west of the building and it is suggested this will have a cooling effect on hot western winds in summer. The beneficial effect of mature vegetation has also been explored and the courtyard areas have been filled with trees and plants. It is claimed that one mature tree can have the cooling effect of five small air conditioners (Asimakopoulos and Santamouris, 1997 *Passive Cooling of Buildings*, James & James).

Thermal mass. Having regard to the high summer and low winter temperatures in Albury, good building envelope design is crucial to minimise demands for artificial heating and cooling. With high summer diurnal temperature swings there is an opportunity to use thermal mass to store night-time 'coolth', and with good winter sunshine there is an opportunity to use thermal mass to store daytime warmth. A typical classroom was computer modelled using the 'Ecotect' software, and different wall specifications were examined to minimise total energy demand for heating and cooling. High thermal mass insitu concrete slab-on-ground floors are accompanied by 'reverse veneer' external wall construction to west, south and east – concrete blockwork walls exposed internally and with insulation and cladding on the outside.

06

07

06 & 07 The rooflight along the ridge of each room introduces natural light internally, thereby reducing the need for artificial lighting and associated energy consumption.

To the north, external walls up to sill height below larger windows are constructed from uninsulated 'rammed earth' 600mm thick onto which winter sun shines to create a heat sink that is intended to balance potential heat losses through the uninsulated wall or radiate warmth back into the building.

Solar access (insolation). Effective use of thermal mass is directly linked to effective admission of sun in winter and effective exclusion of sun in summer. Shading analysis was carried out using the 'Ecotect' software. The roof overhangs to the north, and associated pergolas, and the roof configuration to the monitor rooflight, all ensure that there is no unwanted sun penetration into rooms in summer. The TAFE design guidelines specifically stipulate that there should be no direct sun penetration into classrooms at any time. This precluded the most effective use of winter sun to warm thermal mass inside. The pergolas to the north facades could, as they are, have admitted winter sun while excluding summer sun, but a horizontal panel of fibre cement on the top of each pergola eliminates winter sun penetration into the classrooms. On the cold winter morning that we visited the project, students and teachers rushed for the one room at the west of the teaching wing which has no pergola, because of its warmth due to direct sun penetration – this room was not originally designated as a teaching space. The 'Ecotect' modelling of the typical classroom demonstrated that winter heating energy demand was much greater than summer cooling demand and thus a major energy factor which begs the question – if TAFE guidelines permitted, could more benefit have been made from direct solar access in winter?

Insulation. The specifications were determined through computer modelling. Insulation is included in the lightweight roof construction (R-3.0) and at the edges of insitu concrete slab on ground floors (30mm polystyrene). The 'Ecotect' computer modelling exercise to select the optimum wall construction looked at four insulation/thermal mass alternatives – conventional brick veneer (brick on the outside insulation on the inside), 'reverse veneer' (masonry on the inside and insulation on the outside), 300mm rammed earth (with no insulation) and 'reverse' rammed earth (150mm rammed earth inside with insulation on the outside). The thermal performance of all these options appeared to be quite similar except on sunny days in summer and winter. Energy demands for cooling in summer were a low 11 and 22 percent of energy demand for heating in winter. The overall best performer was deemed to be 'reverse veneer' masonry, and thus the main south, east and west walls are constructed of 200mm concrete blockwork insulated on the outside (R-1.5) behind wall cladding.

Reflectivity. A primary strategy for hot climate design is to use light coloured and reflective materials and finishes – particularly on roofs. This has been a tradition in Australia since the earliest white settlement and forms a foundation to a 'vernacular' architecture that might inform contemporary practice. This, of course, does not conform to the planners' (controllers?) obsession with invisibility and perceived harmony and throws into conflict 'conservation' of urban and rural contexts and conservation of the Earth's energy resources. The TAFE NEC is appropriately finished in light colours to maximise reflectivity and minimise solar heat gains.

Ventilation. Considerable thought has been given to optimising natural summer ventilation in the buildings. The narrow plan configuration allows natural cross ventilation of all rooms. The monitor roof light along the ridges of the main roofs allows high level natural ventilation and induces 'stack effect' air movement (hot air rises through buoyancy, as in a chimney) that draws potentially cool air through the rooms from low level wall vents on the south side of the building and from vents under the north facing windows. This promotes 'physiological' cooling – improving perceived comfort in humans by introduction of air movement (Allard, 1998 *Natural Ventilation in Buildings – a Design Handbook*, James and James). The natural ventilation paths also facilitate night cooling in summer. By opening vents in the evening the cooler night air will circulate naturally through the building and chill down the thermal mass in the walls and concrete floors to emit 'coolth' by day. In a well-designed building in a temperate region with cool summer nights and good thermal mass that is well positioned, when external temperatures in summer begin to exceed internal temperatures, windows and vents can be closed to allow the 'coolth' to work. This does not work, unfortunately, when rooms are used by a large number of heat generating people, lights or equipment.

Daylight. The introduction of the monitor rooflight along the ridge of each room has a dual function. As well as facilitating natural ventilation, it introduces a source of natural light into the centre of the room thus reducing the need for artificial lighting and associated energy consumption. The daylighting design used both 'Ecotect' and 'Radiance' software to model the exact configuration, size and roof pitch of the roof overhangs and the monitor rooflight. Original proposals to pitch the monitor rooflight roof up to the north were reversed to pitch it up to the south to gain a slight advantage from south light without direct sun, and to avoid potential adverse ventilation effects from strong hot northerly buster winds in summer. The required lighting level for reading and working is 300 lux, and one must balance adequate natural light levels in winter with excessive glare in summer. The design solution targets a minimum 100-200 lux of natural light in mid-winter, accompanied by dimmable fluorescent lights on electronic ballasts and light sensors that respond to the need for supplementary artificial light while minimising energy demand. In summer, there is adequate natural light across the classrooms without the need for artificial light.

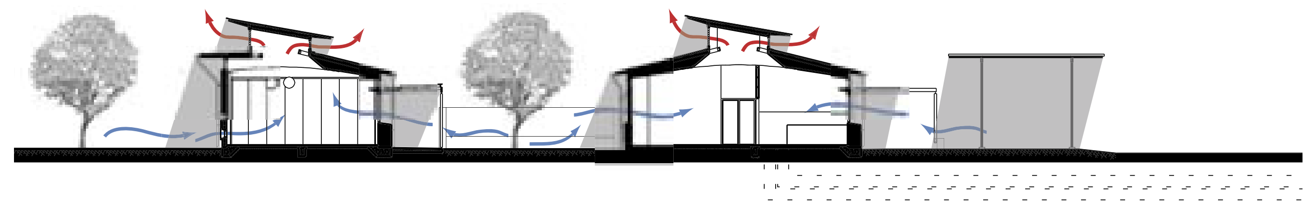
Earth to air heat exchange system. An intriguing feature of the TAFE NEC project is the innovative use of ground cooling for fresh air being introduced into the mechanical ventilation system. Notwithstanding the passive design strategies to achieve thermal comfort in summer, the heat loads generated in a room by 30 students plus equipment will push temperatures up out of the comfort zone thus requiring auxiliary cooling. Two horizontal ducts are suspended through the main rooms at high level under the monitor rooflight to distribute cool air in summer, and warm air in winter. Cooled air is supplied to this duct system from an underground thermal labyrinth of pipes. This air can also be further chilled down by passing air through an evaporative cooler. The underground labyrinth consists of four 300mm diameter plastic pipes about 25 metres long buried two metres below the surface. Fresh air is drawn in by fan from air inlet boxes, with dust filters, remote from the buildings. It has been calculated that for external temperatures up to 35˚C, this earth to air exchange system can use ambient ground temperature at 17˚C to cool incoming air down 6˚C from, for example, 35˚C to 29˚C. This can either pass directly to the rooms through the high level ducts, or be further chilled down to 20˚C by the evaporative cooler which is effective due to Albury's low summer humidity of 33 percent. Some concerns about the inaccessibility for cleaning of the underground pipes of the labyrinth are allayed by low humidity levels and the dust filters on the intakes.

Water. Features of the project include water collection and recycling, swales and dams for capture and storage of irrigation water, solar water heating on roofs, photo-voltaic panels on the roof to run water pumps for circulation and for courtyard ponds and on-site sewage treatment.

Conclusion. A laudable holistic and integrated design approach has been adopted in the TAFE NEC project. The building solutions have been directly informed by a fine-grained assessment of the local climatic conditions and comprehensive environmental computer simulation. The wisdom of conventional good practice has been combined with experimental innovative solutions delivered within a refined architectural vocabulary. It is hoped that proposed monitoring of the performance will be implemented, and that this will show that the building does live up to its design expectations. Such feedback is in short supply in regard to many claimed innovative environmentally responsive projects.

Lindsay Johnston acknowledges the assistance gained from a research paper 'Case Study of the National Environment Centre Riverina Institute Thurgoona Albury' (July 2000) prepared by Zig Peshos, Environmental and Energy Services Group, NSW DPWS as part of his Master of Design Science degree program at the University of Sydney.

Professor Lindsay Johnston is the former Dean of the Faculty of Architecture, Building and Design at the University of Newcastle, NSW.

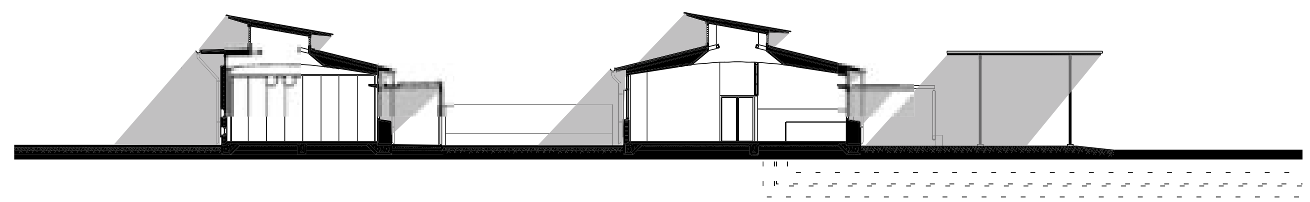


Courtyards – summer condition
Building shaded with air drawn from cool sources

Shade and cooling from landscape with misting to rear

Shade and cooling from landscape with misting to courtyard

Shade and cooling from shade structure with misting

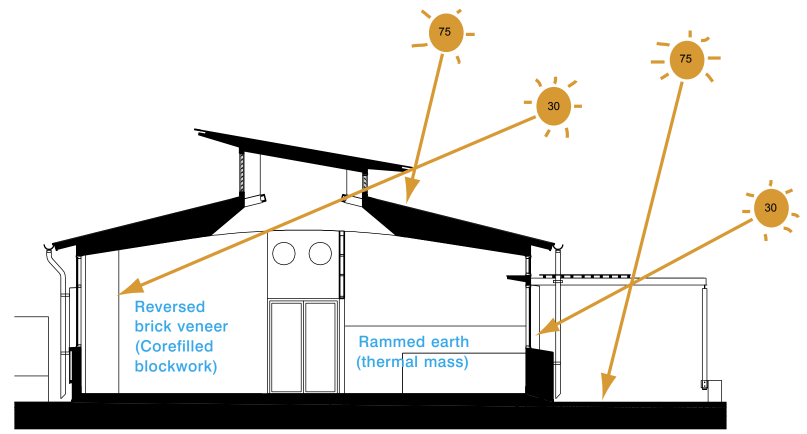


Courtyards – winter condition

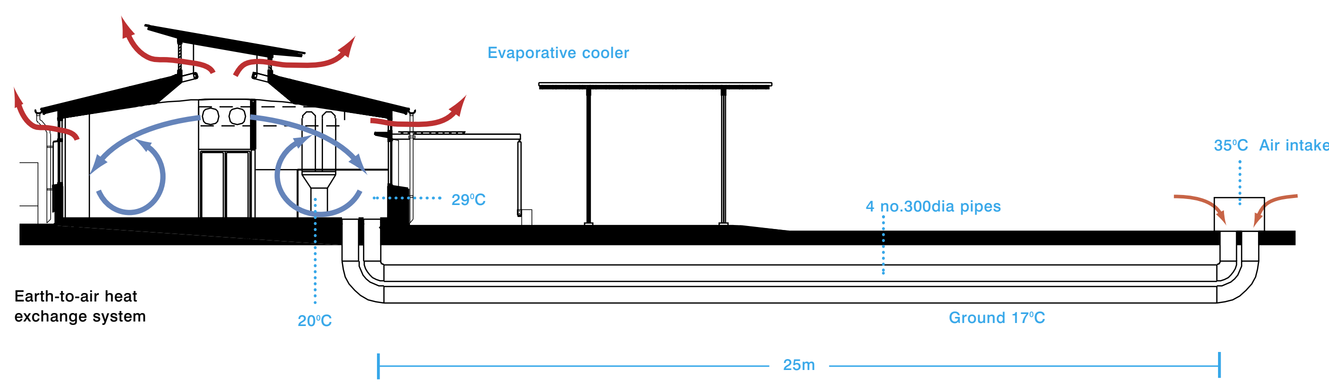
No misting

Deciduous trees for solar gain to courtyard – no misting

No misting



Large scale cross section showing construction materials and sun angles



Earth-to-air heat exchange system

Project Summary TAFE National Environment Centre ■ **Design architects** Lindsay and Kerry Clare ■ **Project architect** Peter Poulet, DPWS ■ **Architects** Carlo Sogari and Evan Pearson, DPWS ■ **Project manager** Malcolm Kite, DPWS ■ **Environmental designers** Zig Peshos and Eric Yeo, DPWS ■ **Landscape architects** Penny Allen and Nicole Thompson, DPWS ■ **Structural engineer** Vijay Badhwar, DPWS ■ **Electrical engineer** Steve Hennessey, DPWS ■ **Mechanical engineer** San Mai, DPWS ■ **Hydraulics engineer** Ken Couzens, DPWS ■ **Builder** ABA Constructions